



Armed Forces College of Medicine

AFCM



Capillary circulation, tissue fluid formation and edema

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INTENDED LEARNING OBJECTIVES (ILO)



By the end of this lecture the student will be able to:

1. Correlate the capillary structure to its function
2. Describe tissue fluid formation “starling forces”
3. Explain how transcapillary fluid movements will be involved in the overall cardiovascular response to a given primary disturbance.
4. Define edema, list its causes and describe its mechanism

Apply the information studied in this section to solve a clinical problem or explain clinical case.

Functional histology



- Capillaries are the smallest type of blood vessels which form the junction between the arterial and the venous ends of the circulatory system.
- Generally speaking a capillary is about $750\mu\text{m}$ in length and $60\mu\text{m}$ in diameter.
- Only 25% of all the capillaries are open while the remaining is closed.



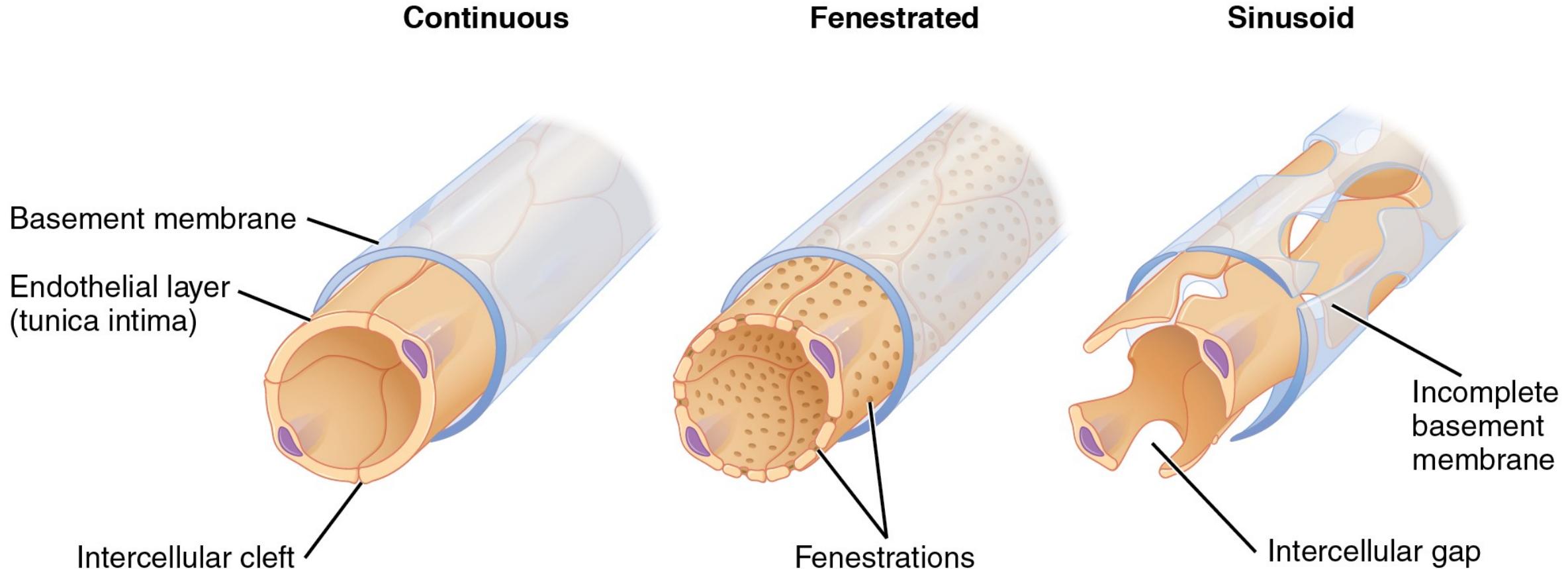
Types of capillaries

Non-fenestrated

Fenestrated

Sinusoids

Functional histology



https://commons.wikimedia.org/wiki/File:2104_Three_Major_Capillary_Types.jpg

Functions of the capillary circulation



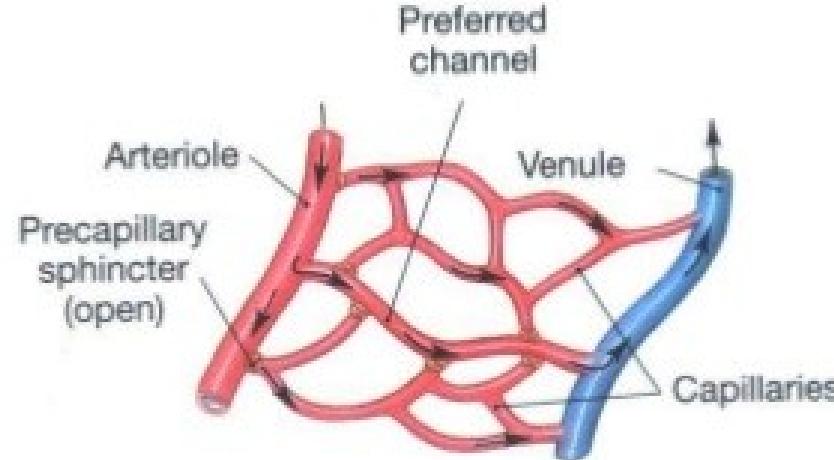
- 1-It is responsible for nutrition of the tissues with oxygen and different nutrients.**
- 2- It is responsible for drainage of waste products from these tissues.**
- 3-It is responsible for determination of the skin colouration.**
- 4-It is responsible for the formation of the interstitial tissue fluid.**

The capillary blood flow

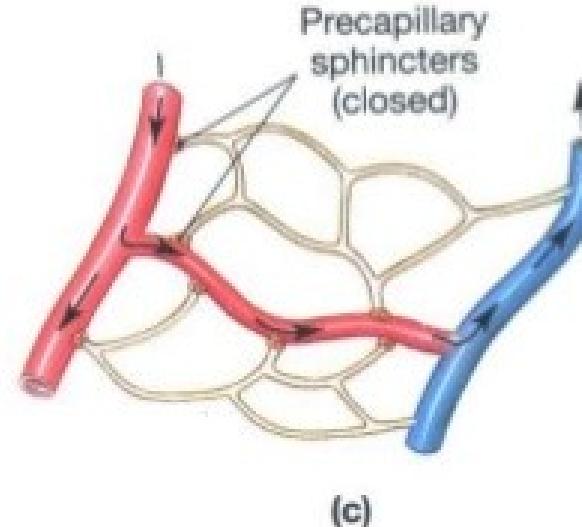


- The capillary blood flow is not a continuous but an intermittent type of flow.
- This is known as the capillary vaso-motion.

The capillary blood flow



Vasomotion



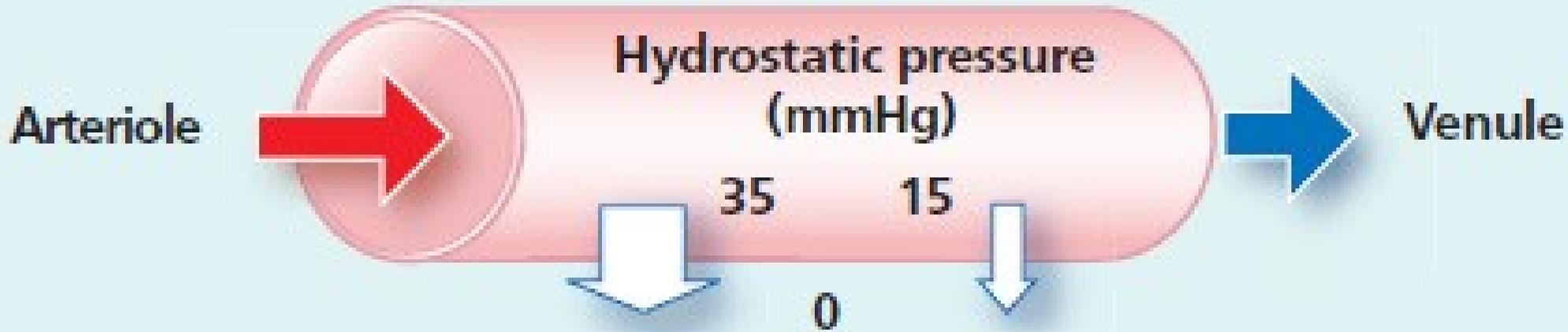
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Mechanism of the capillary vasomotion



- The pre-capillary sphincters are richly supplied by the sympathetic nerve fibers, they gradually constrict under the sympathetic tone and with maximum constriction the capillaries are fully closed and blood inflow stops temporarily.
- With full closure of these capillaries there will be ischemia, hypoxia and acidosis which eventually will dilate these sphincters leading to reopening of these capillaries, so that blood re-inflows into them.
- Blood flow will wash out all metabolites relieving hypoxia, ischemia and acidosis with the sympathetic tone regaining its full activity gradual.
- The intermittent closure occurs at a rate of 6-12/min.

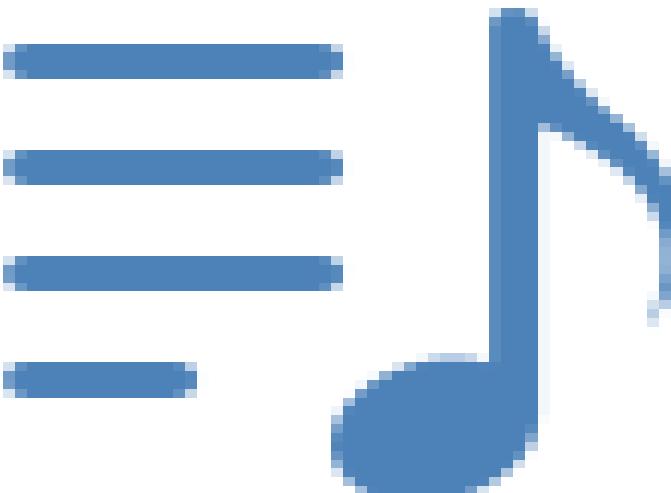
The Capillary Blood Pressure



https://dm30mg1n1n7zx.cloudfront.net/rcni/static/journals/ns/18/51/ns.18.51.45.s54/graphic/ns_v18_n51_54_0004.jpg

- The mean capillary blood pressure is 25 mmHg.
- The capillary pulsations at the arterial end are normally invisible because they are very faint.
- These pulsations become visible only with any condition of hyper-dynamic circulation as in arterial vasodilatation, AV shunts, thyrotoxicosis and aortic incompetence.

The nail bed test



https://www.youtube.com/watch?v=9m_0RAQDFH

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Factors affecting the capillary blood pressure



1-The precapillary sphincter

2-The post-capillary sphincter

3-The arterial blood pressure

4-The venous pressure:

Characteristics of the capillaries



(A) The capillary fragility:-

- It means how much pressure the capillary wall can adapt or accommodate without being ruptured.
- The fragility is dependent upon healthy capillary wall which is formed mainly of collagen.
- Any disruption of the collagen synthesis will markedly affect the wall integrity and increase its fragility.

Characteristics of the capillaries



-Factors affecting the integrity of collagen synthesis in the capillary wall:-

- 1- Intact protein synthesis of collagen.
- 2-Adequate supply of vitamin C

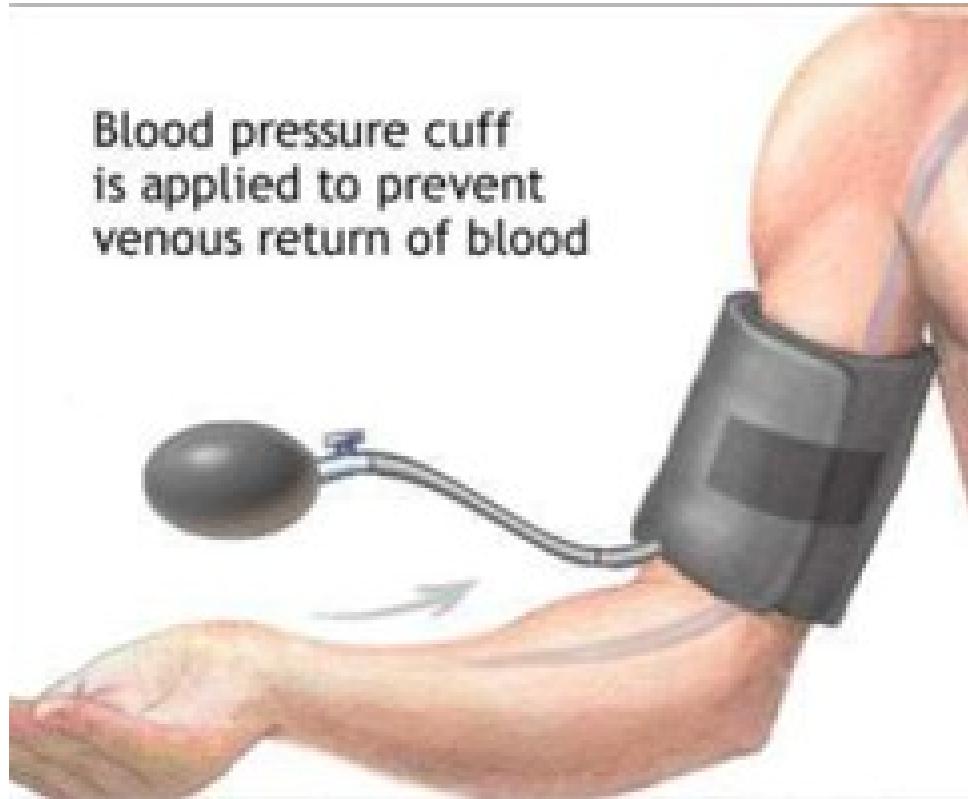
-Causes of increased capillary fragility:-

- 1- Excess cortisol which disrupts collagen synthesis.
- 2- Deficiency of vit.C and /or Rutin.
- 3- Inflammation of the walls of capillaries; capillaritis.
- 4-Excess exposure to sun rays.

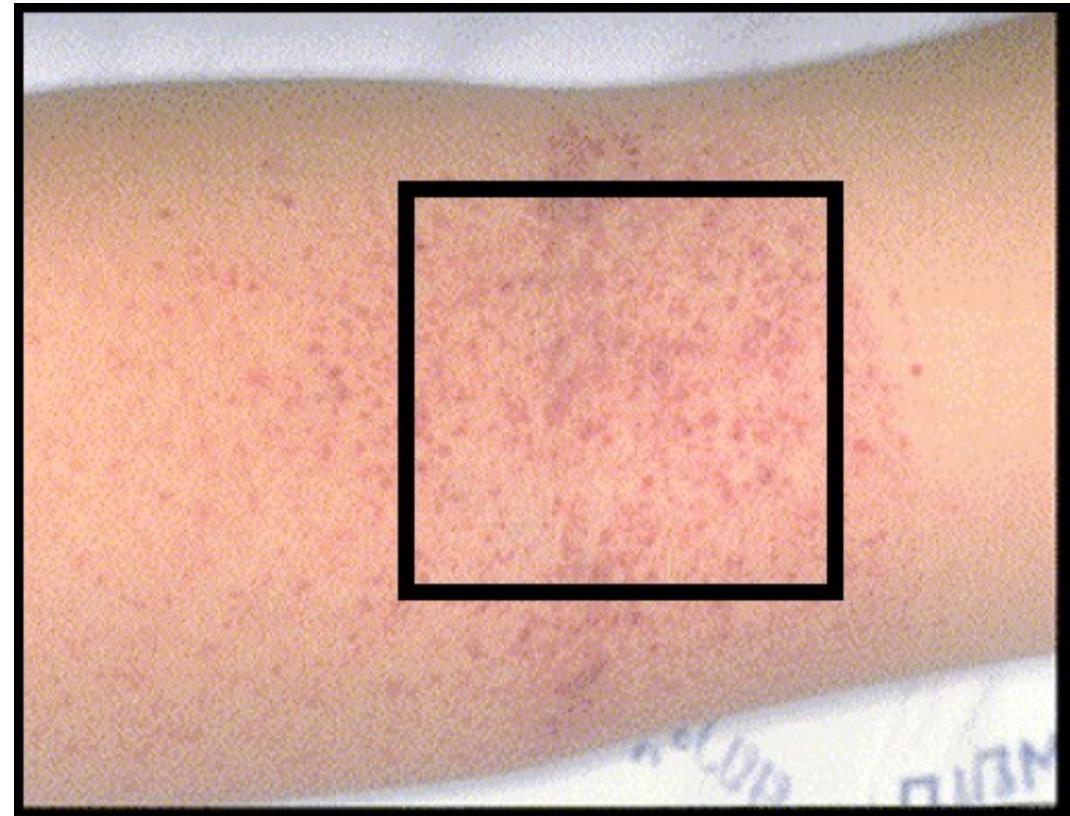
Characteristics of the capillaries



- *-Testing of capillary fragility; Hiss test:*



<https://quizlet.com/cdn-cgi/image/f=auto,fit=cover,h=200,onerror=redirect,w=240/https://o.quizlet.com/mU2R7dEIDgL.8P6CYqUJTg.png>



<https://www.cdc.gov/dengue/training/cme/ccm/images/Tourniquet%20test1.png>

Characteristics of the capillaries



(B) The capillary permeability:-

- Permeability of a membrane is defined as its criterion that allows the passage of substances through it in either or in both directions.
- Permeability of the capillary wall is an important determinant factor which controls the interstitial tissue fluid formation.

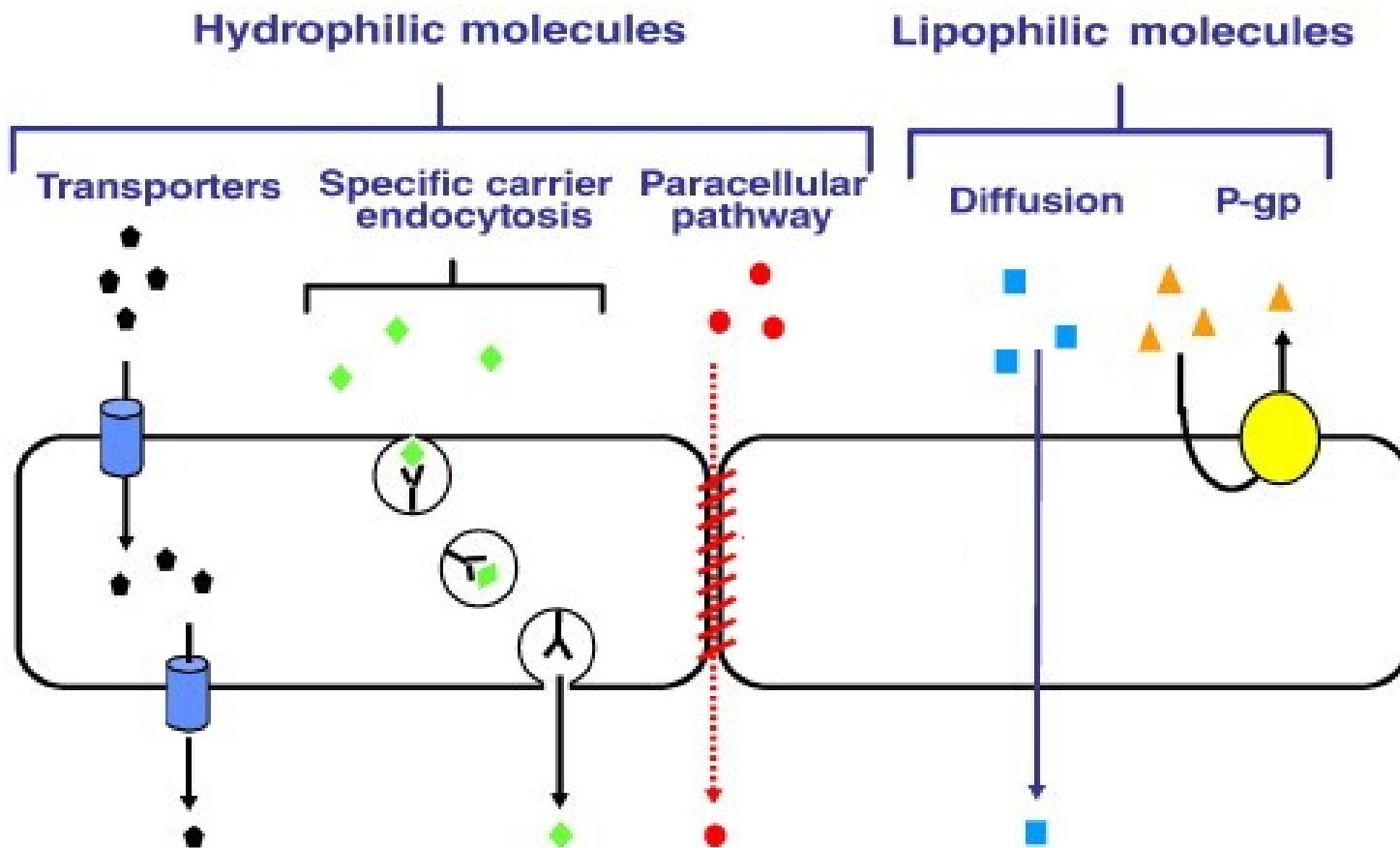
Characteristics of the capillaries



Permeability is affected by the following factors:-

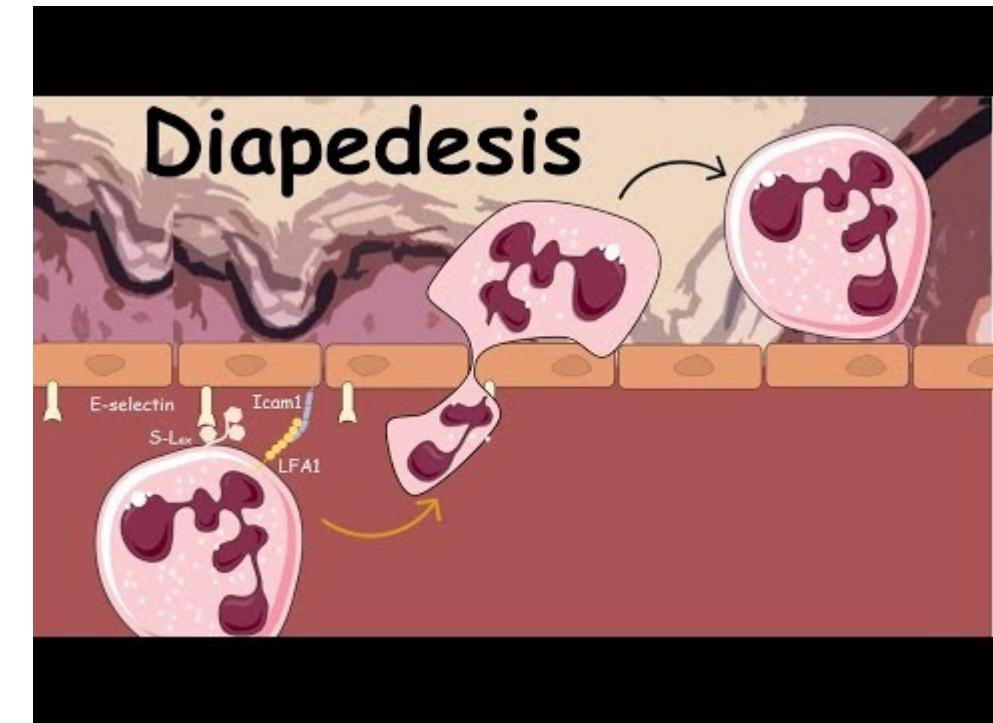
- 1-Serum Ca ion level:-Ca solidifies the protein cement bridges between the cells in the capillary wall, so any decrease of the Ca ion level will increase the capillary wall permeability.
- 2-Acidosis:-it increases Ca ion solubility thus preventing its binding to the protein bridges.
- 3-Hypoproteinaemia:-as some of the plasma proteins block the capillary wall intercellular pores.
- 4-Capillary vasodilatation: - it automatically increases permeability as it widens the pores.
- 5-Ischemia and hypoxia: - they both lead to capillary vasodilatation. They may also lead to acidosis.
- 6-Vasodilators as histamine and bradykinin ; they increase the capillary permeability.
- 7- Vit. C and Rutin deficiency:-they decrease the capillary permeability.
- 8-Extremes of temperature decrease the capillary permeability.

The Trans-capillary transport of substances



<https://ars.els-cdn.com/content/image/1-s2.0-S0969996109002071-gr1.jpg>

Cardiopulmonary Module



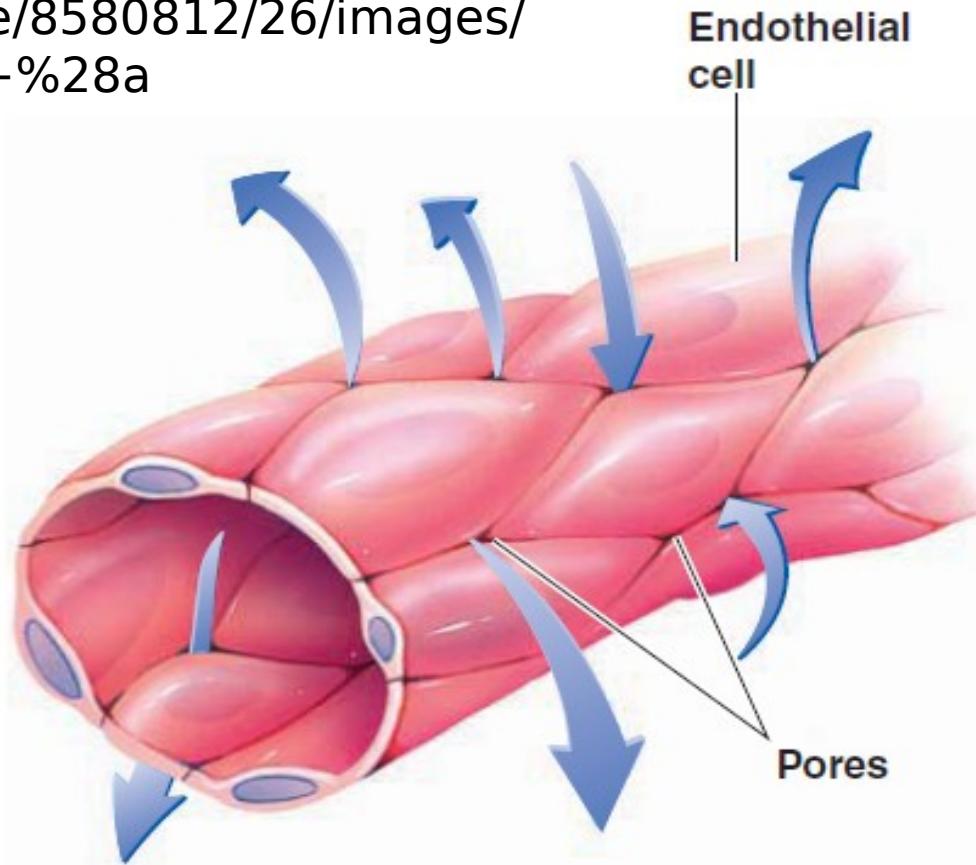
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Trans-Capillary Filtration



Bulk

<https://slideplayer.com/slide/8580812/26/images/30/Endothelial+cell+Pores+%28a%29+Typical+capillary.jpg>



The Interstitial tissue fluid formation



- At the arterial end of capillaries about 20 liters of fluid are filtered daily into the interstitium.
- At the venous end about 18 liters are reabsorbed daily, the remaining 2 liters are delivered by the lymphatic system.
- The interstitial fluid acts as a device for nutrition and drainage for the tissues.

Mechanism of tissue fluid formation

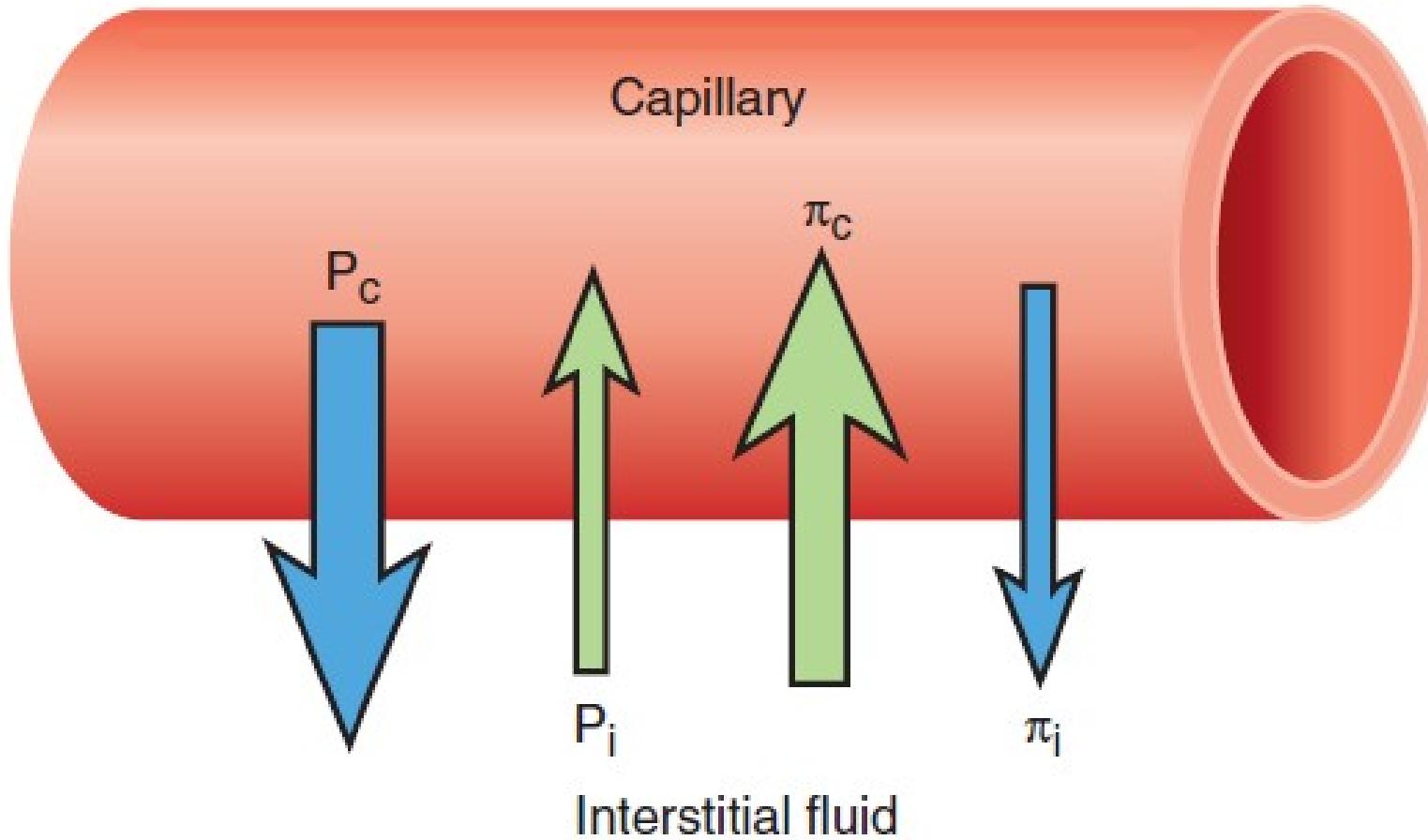


- A group of forces called starling forces act at the arterial and venous ends of the capillaries for formation of the tissue fluid.
- They are simply the filtering and the re-absorptive forces

Mechanism of tissue fluid formation



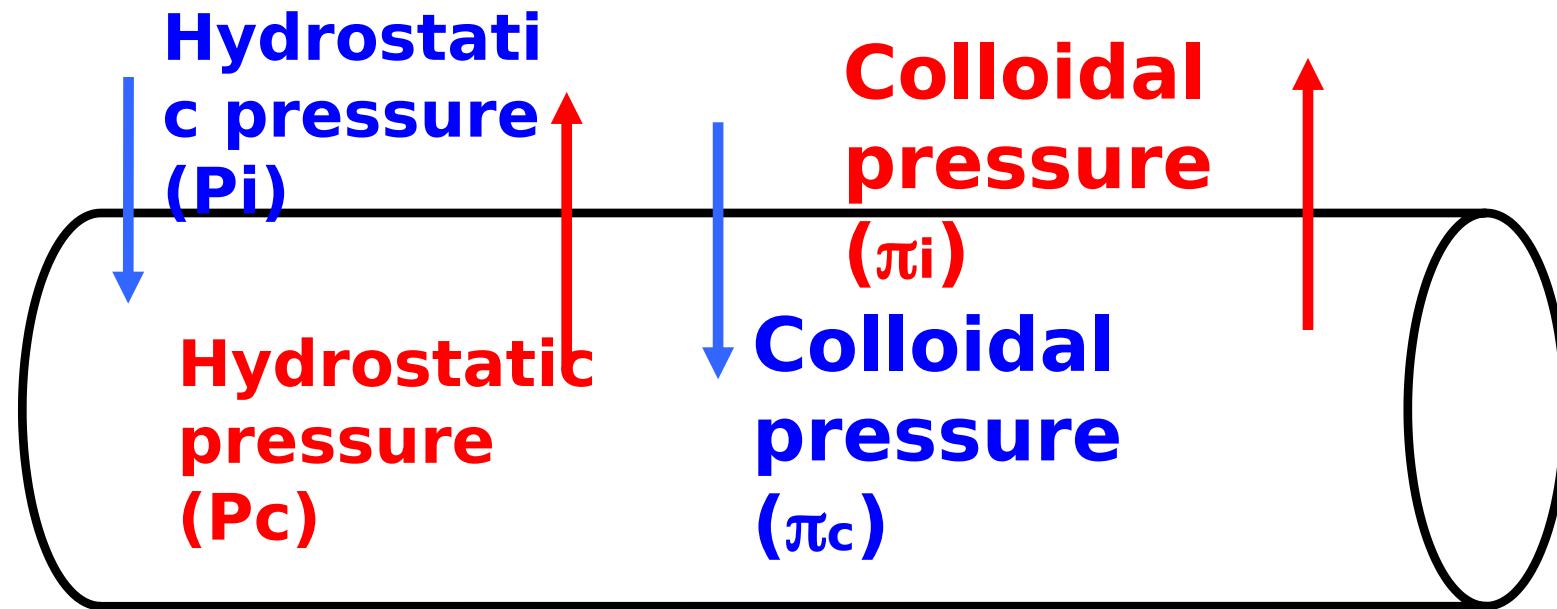
Trans-Capillary Filtration Bulk flow



Factors affecting the tissue fluid formation

Trans-Capillary Filtration

Bulk flow



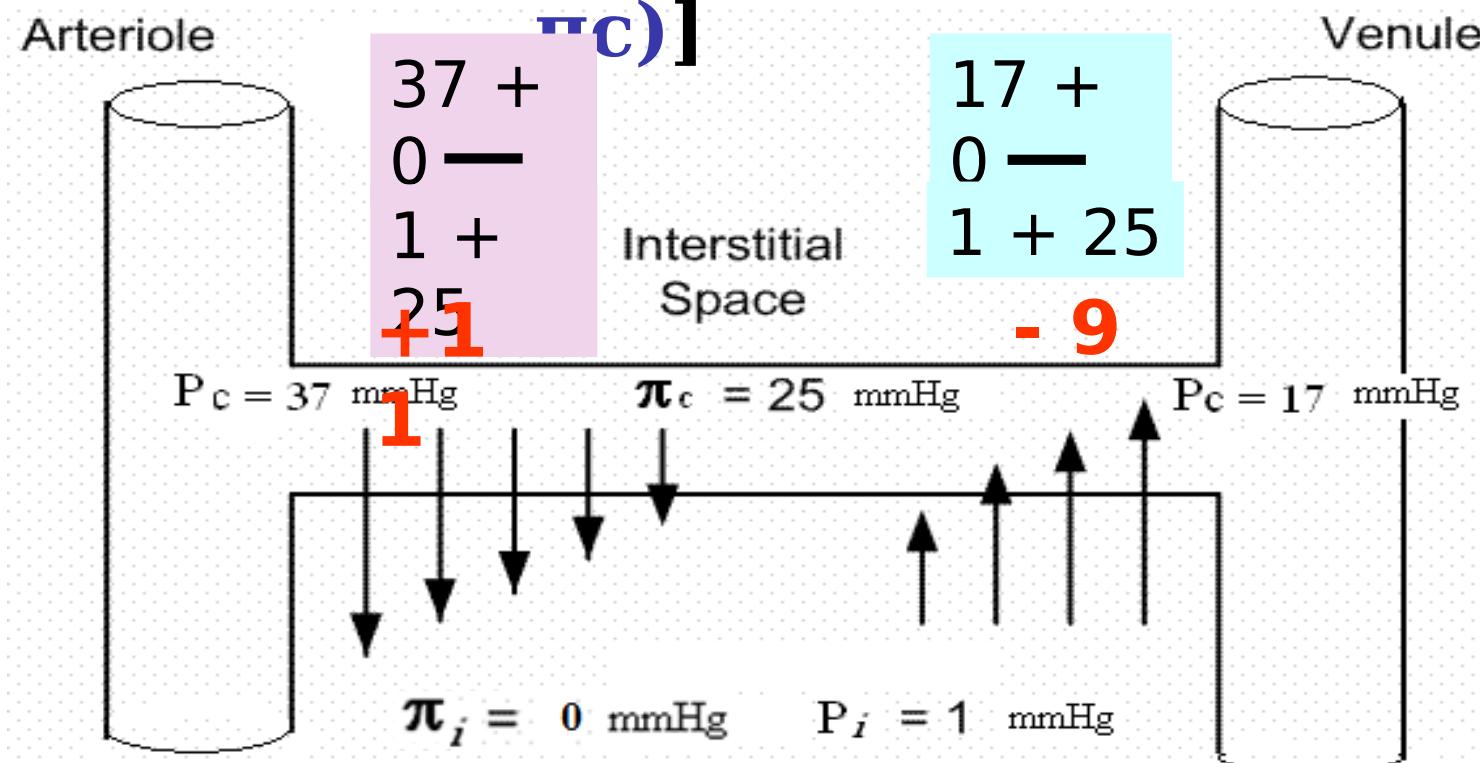
Net force = $[(P_c + \pi_i)] - [(P_i + \pi_c)]$
Filtration \propto Net force

$$\text{Filtration} = K \left[(P_c + \pi_i) \right] - \left[(P_i + \pi_c) \right]$$

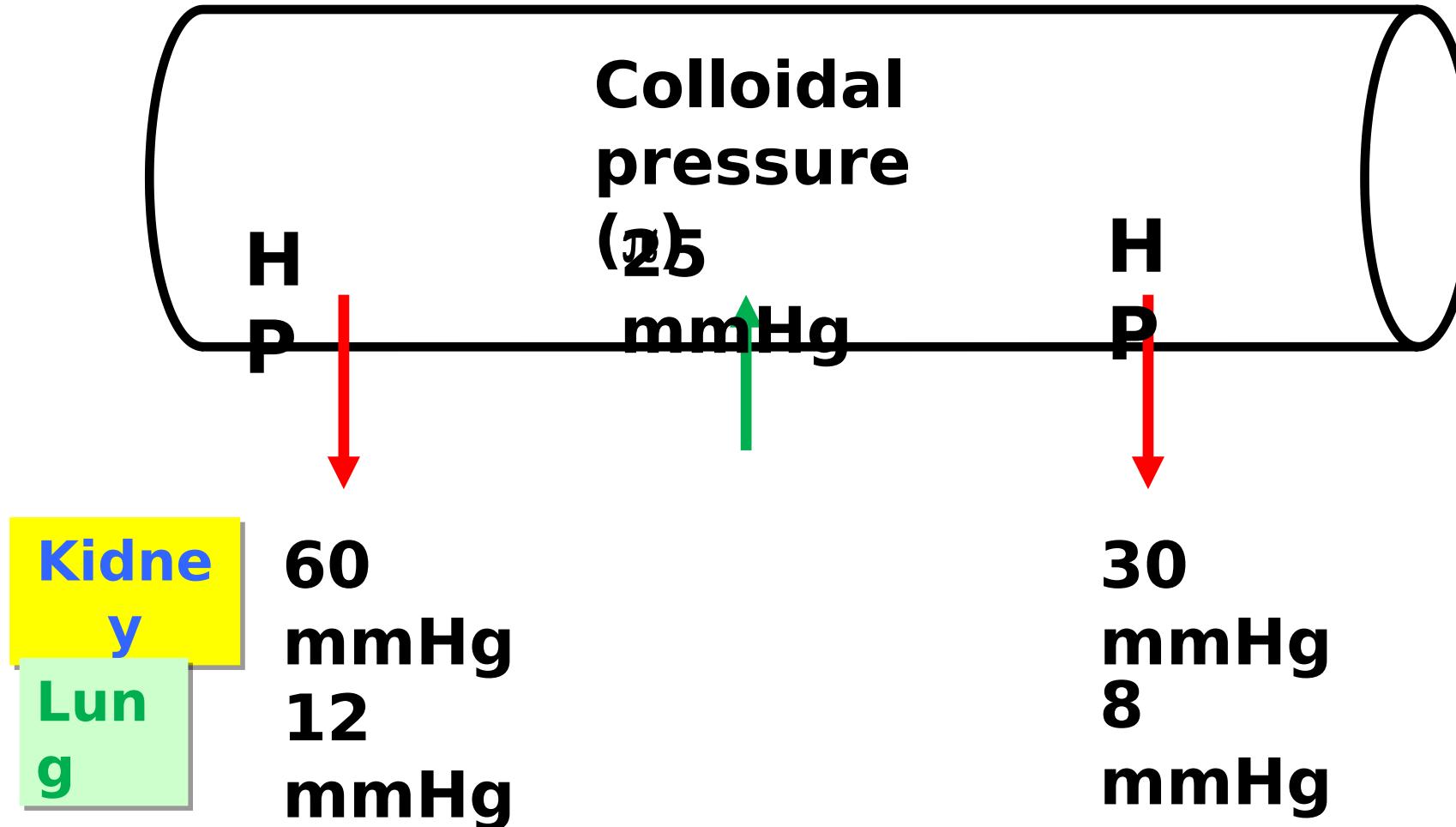
Starling forces



$$\text{Net force} = [(P_c + \pi_i)] - [(P_i + \pi_c)]$$



Starling forces





- It is defined as any increase of the tissue fluid volume.

Types of oedema

Intracellular

Extracellular

Oedema

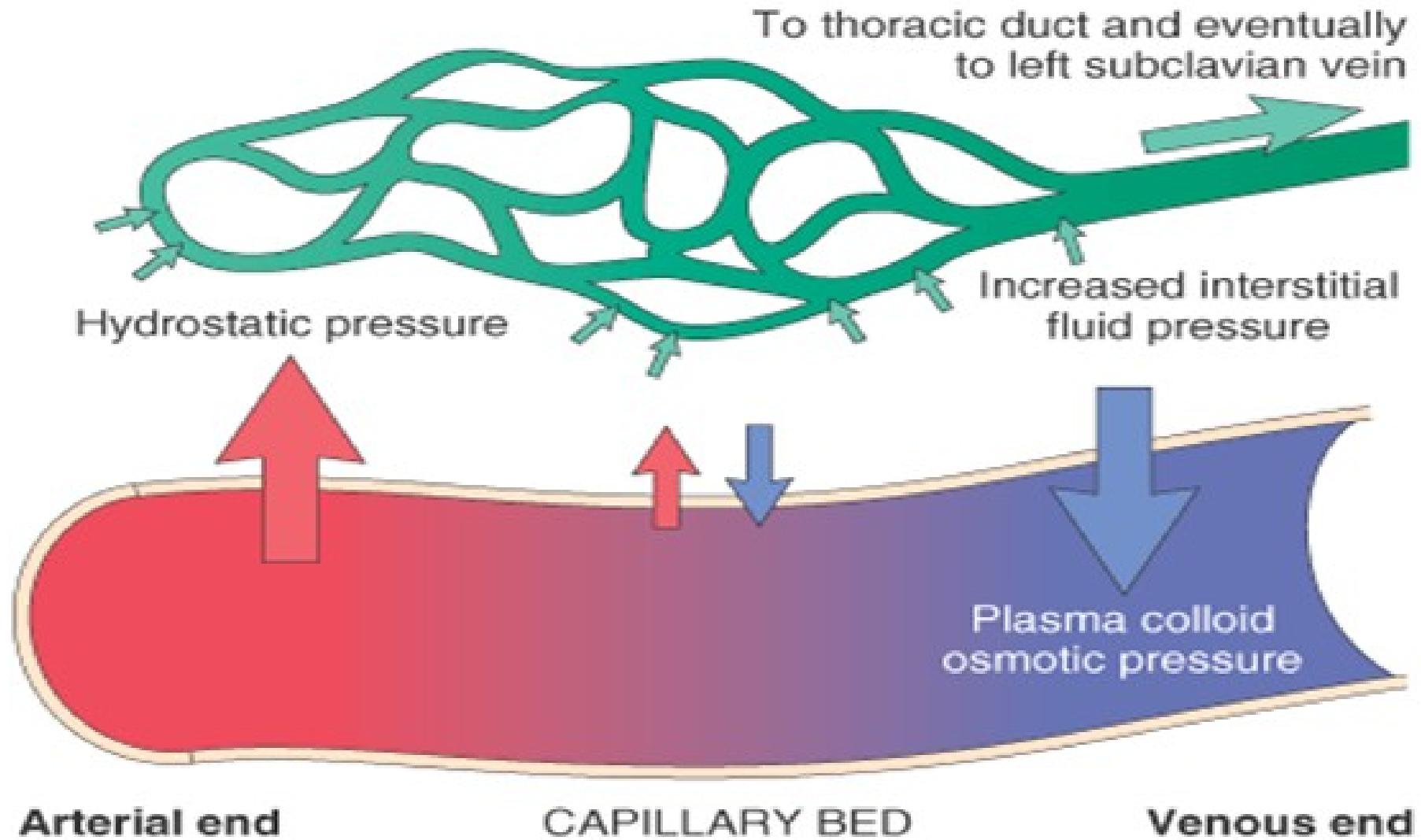


- **1-Intracellular oedema:-**where the intracellular fluid volume is increased.
- **-Causes:-**
- a-Depression of the Na-K pump, leading to an increase of the intracellular Na concentration with water flowing into the cells.
- b- Increase of the cell wall permeability due to allergy, inflammation, ischemia or hypoxia.

Oedema



- **2-Extracellular oedema:-**
- -The interstitial fluid volume is increased.



https://1.bp.blogspot.com/-7GBgafuJF14/TWOM6S12E_I/AAAAAAAACrs/SSPVXwNreok/s1600/Fluid%2BCirculation.png



abnormal large accumulation of fluid

Causes of edema

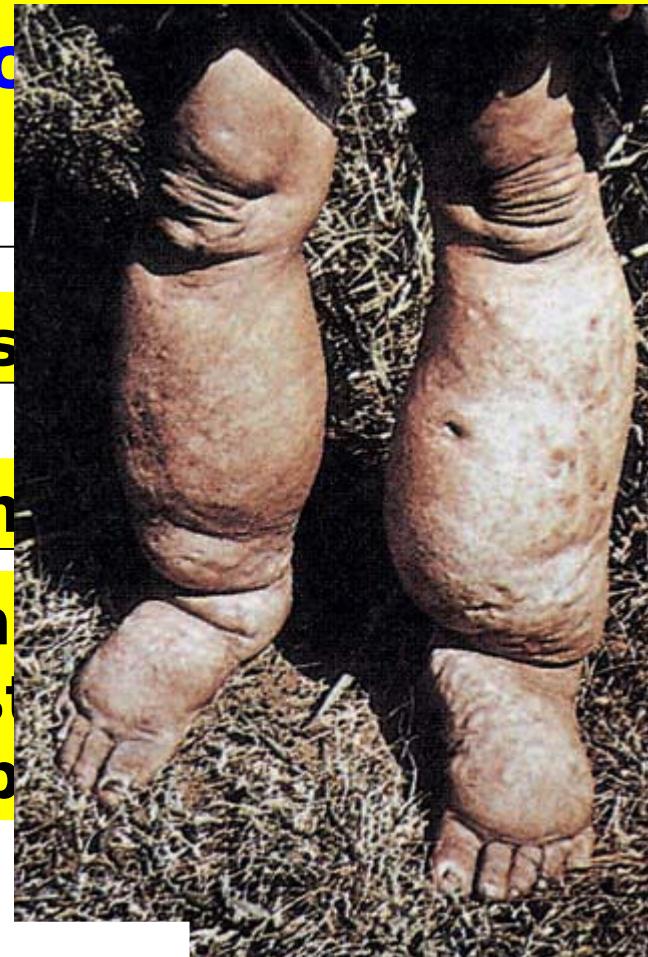
- 1- **Increased Filtration**
- 2- **Decreased Osmotic Pressure Across Capillary**
- 3- **Increased Capillary Permeability**
- 4- **Inadequate Lymph Flow:**

Arteriolar dilation.
Venular constriction
Increased capillary permeability

Decreased plasma oncotic pressure

Histamine
Substances

Lymphatic obstruction
elephantiasis





Test your knowledge



(1) Increased capillary _____ pressure, is one of the most common causes of edema.

- (A) Osmotic
- (B) Oncotic
- (C) Hydrostatic
- (D) Diastolic

Test your knowledge



(2) Decreased capillary_____ pressure, is one of the causes that leads to edema.

- (A) Hydrostatic
- (B) Colloid osmotic
- (C) Crystalloid
- (D) Pulse

References



1. Guyton and Hall Textbook of Medical Physiology.

- <https://www.amazon.com/Guyton-Hall-Textbook-Medical-Physiology/dp/1455770051>

2. Ganong's Review of Medical Physiology, 25e.

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<https://www.amazon.com/Ganongs-Review-Medical-Physiology-Twenty-Fifth/dp/007182510X>



Thank
you

